TEM and XRD study of nano-graphene layer formation and texturing in carbon films deposited by pulsed Nd:YAG laser

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Abstract

Nano-structured carbon films are very interesting electronic material, since many electronic properties, like charge transport and low threshold field emission [1], are highly anisotropic and generally correlated to the basal plane orientation of graphene layers and to the peculiar electron energy density of states of the aromatic emission sites, associated with the π band [2]. These properties are expected to open new perspectives of technological applications.

In our work, we tried to study and model how deposition temperature can affect the aromatic particle formation and control a definite texture and growth orientation. We exploited the capability of Pulsed Laser Deposition (PLD) to deposit nano-structured carbon films, with different level of sp^2 coordination and examined the peculiar role of substrate temperature driving a preferential orientation of graphitic nano-particles with respect to Si <100> substrate.

Pulsed laser ablation of a rotating pyrolytic graphite target (Nd:YAG laser, 2nd harmonic: λ=532 nm, hν=2.33 eV, τ=7 ns, ν=10 Hz, $\Phi \approx 7$ J/cm2), operating in vacuum (~ 10-7 mbar) at temperature ranging from RT to 900 °C has been used to prepare thin films of carbon [3]. Synchrotron X-ray diffraction, performed at grazing incidence and high resolution, established the formation of nano-sized (~7 nm) graphene structures at higher deposition temperatures (~ 900°C). These structures resulted to be formed by some parallel graphene layers (4-5), characterised by a well defined longitudinal growth (along the graphene sheets), with č axis parallel to the substrate. High resolution TEM images and selected area electron diffraction (SAED) patterns confirmed both size and orientation of these graphene nano-particles determined by X-rays.

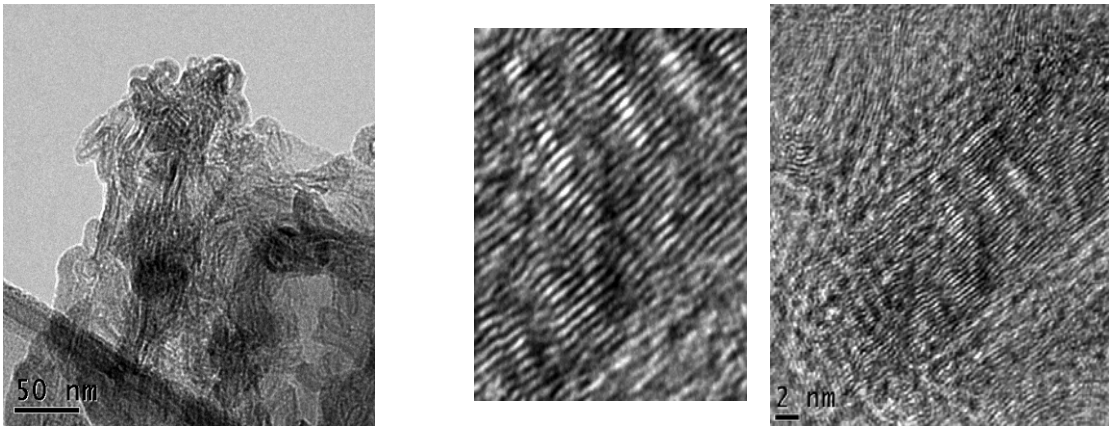

fig. 1. GRID-TEM picture of high temperature carbon nano-graphene layers taken at different magnifications

In the samples deposited at RT, taking constant the other conditions, the typical structure of random amorphous carbon material has been obtained.

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The mass density of the deposited films, as measured by laboratory X-ray reflectivity, is also strongly dependent on the substrate temperature: films grown at room temperature show higher density than the samples deposited at high temperature.

We consider that the preferred growth direction of nano-graphene layers results from cooperating effects of thermal surface diffusion, preferential in-plane growth of graphene sheets and line source direction of the feeding activated species of the laser carbon plume.

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